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The Effects of Microcirculation on ADC Map: Computer Simulation

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Purpose: In general, the MR signal loss in a single voxel results from dephasing effect of intravoxel incoherent motion (IVIM). The sources of IVIM can be several. The first source is diffusion. However, the accurate estimation of the effect of diffusion is sometimes difficult due to another source of incoherent motion, that is, microcirculation within a voxel. In this study, the microcirculation effects took into account explicitly and the effects on ADC estimation were evaluated.

Materials and Method: The microcirculation (perfusion) was considered as a pseudo- diffusion process by assuming that water molecules in the capillary network frequently change direction during the MR measurement time. Macroscopically, microcirculation then appears as a random walk process. The resulting MR signal attenuation can then be modeled as bi-exponential:
$A = (1-f)\ exp(-bD) + f\ exp(-b[D_*+D])$
where D_* is the pseudo-diffusion coefficient of microcirculation. Based on this model, the values of ADC was estimated along the different f and D_*. The simulation was performed using MATHCAD software and the ADC values were calculated using non-linear least square fitting program.

Results: The result shows that the last points of the attenuation curve which corresponds to large b values represent almost exclusively diffusion, because perfusion effects have been canceled out by large gradients. The microcirculation effects can be seen on small b values. As capillary fraction (f) increases from 0.0 to 0.4, ADC values increase linearly from $1.2\times10-3$ to $1.7\times10-3$ mm^2/sec. However, the increase of D_* gave less effect on ADC. At $f = 0.1$, the range of increase in ADC was shown to be limited within $0.25\times10-3$ mm^2/sec.

Conclusion: Both capillary fraction (f) and pseudo-diffusion coefficient (D_*) play important roles in determining accurate ADC value.